

General Report of TC 215 Environmental Geotechnics

Rapport *énéral du TC 215 Géotechnique de l'environment

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ABSTRACT: Twenty two (22) papers have been allocated to this session. They originated from twelve (12) countries and five (5) continental regions (Asia, Europe, North America, South America and Oceania). They described and presented laboratory and field studies and numerical modelling addressing numerous topics which included novel materials, chemical compatibility of barrier materials, unsaturated behaviour of geosynthetic liners, soil-geosynthetic liner interface behaviour, waste geotechnical properties, phytoremediation, permeable reactive barriers, soil and groundwater remediation, image analysis, natural leaching of heavy metals and biogeotechnology. This general report offers a review of all the papers submitted to this session and highlights the major findings reported by the authors of these papers.

RÉSUMÉ : Vingt-deux (22) communications ont été allouées à cette session. Elles proviennent de douze (12) pays et de cinq (5) régions continentales (Asie, Europe, Amérique du Nord, Amérique du Sud et Océanie). Ces communications décrivent et présentent des études de laboratoire et sur site ainsi que des études de modélisation numérique. Elles traitent de nombreux sujets comprenant les nouveaux matériaux, la compatibilité chimique des matériaux d'étanchéisation, le comportement insaturé des géosynthétiques, le comportement de l'interface sol-géosynthétique, les propriétés géotechniques des déchets, la phytoremédiation, les barrières réactives perméables, l'assainissement des sols et des eaux souterraines, l'analyse d'images, le lessivage naturel des métaux lourds et la biogéotechnologie. Ce rapport général présente une revue de tous les documents soumis à cette session et met en évidence les principaux résultats rapportés par les auteurs de ces documents.

KEYWORDS: biogeotechnology, containment barriers, geotechnical properties, groundwater, soil, remediation, waste,

1 INTRODUCTION

Environmental Geotechnics has evolved dramatically from the 1980s/1990s practice where the focus was on addressing problems related to contaminated sites as well as waste management. Nowadays, the discipline has expanded dramatically to tackle new challenges brought about by a continuous evolving world. Energy (geothermal energy, CO₂ sequestration, coal seam and shale gas, methane hydrates, etc.), oil and gas resources, mining, reservoir engineering, effect of climate change on built structures and biogeotechnical engineering, are examples of areas Environmental Geotechnics has expanded to. Consequently, this had the effect of bringing other different disciplines (chemistry, biology, soil science, etc.) even closer than before.

Significant and rapid progress in research and development has enabled the development of Environmental Geotechnics as a discipline to the level where it is now. This is reflected by the contributions made to this session which includes novel materials to deal with very aggressive solutes to biological approaches to restore land devastated by natural events.

Twenty two (22) papers have been allocated to this session. They originated from twelve (12) countries and five (5) continental regions (Asia, Europe, North America, South America and Oceania). Most papers have presented laboratory studies. Papers including field studies and numerical modelling were also presented. The papers have been grouped into the following themes:

- Containment barriers
- Municipal solid waste and other types of waste geotechnical properties
- Soil and groundwater remediation
- Biogeotechnology

This general report offers a review of all the papers submitted to this session. It highlights the major findings reported by the authors of these papers.

2 CONTAINMENT BARRIERS

Bohnhoff et al. describe a study on bentonites that have been chemically modified to achieve greater chemical compatibility when used as containment barriers such that the desirable engineering properties of the bentonites are not compromised. They have considered three bentonites. These bentonites include **(1)** a natural Na-bentonite polymerized with acrylic acid to form polyacrylate polymerized bentonite, referred to as a bentonite polymer nanocomposite or BPN, **(2)** a propylene carbonate (PC) modified Na-bentonite, referred to as "multiswellable bentonite" or MSB, and **(3)** Na-bentonite amended with sodium carboxymethyl cellulose (Na-CMC), referred to as "HYPER clay" or HC. Two potential applications were considered: 1) soil bentonite (SB) vertical cut off walls and 2) geosynthetic clay liners. In both cases hydraulic conductivity to water and CaCl₂ solutions were compared with those of three natural Na-bentonites commonly used in geoenvironmental containment applications. Permeation with deionised water, DIW, (plotted at 0.1 mM CaCl₂ in Fig. 1) resulted in low k_w (i.e., 4.2×10^{-12} to 3.4×10^{-11} m/s) regardless of the bentonite type. However, the BPN, HC2, and MSB exhibited superior hydraulic behaviour (i.e., lower k_c) relative to the GCL bentonites. The influence of CaCl₂ on the k of backfill specimens containing 5.7 % NB1 or 5.6 % MSB and specimens containing 7.1 % NB2, 2.4 % BPN, and 5.5 % BPN is shown in Fig. 2b. All of the specimens were susceptible to an increase in k , i.e., $k_c/k_w > 1$, where k_c = hydraulic conductivity to the CaCl₂ solution, when permeated with ≥ 10 mM CaCl₂ solutions. The increases varied from approximately two-fold to 15-fold depending, in part, on the

bentonite content. The authors indicated that the differences in behaviour among these novel bentonites illustrated in this paper highlight the need for further research into the specific mechanisms affecting the performance of such new materials. At the same time, the paper shows the potential that such bentonites can have in addressing aggressive solutes.

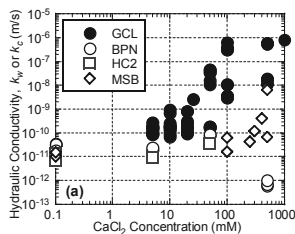


Figure 1 Hydraulic conductivity of bentonite specimens as a function of (a) CaCl_2 concentration in the permeant liquid (Bohnhoff et al., 2013)

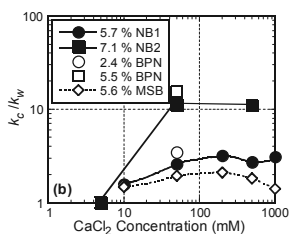


Figure 2. Permeation results for sand-bentonite backfills: ratio of hydraulic conductivity to CaCl_2 solution, k_c , relative to hydraulic conductivity to water k_w as a function of CaCl_2 concentration (Bohnhoff et al., 2013)

Brianzoni et al. report the results of a research study aimed at evaluating and predicting the long term hydraulic performance of cement bentonite (CB) mixtures used in cut off walls when in contact with saline solutions (K_2SO_4) or acidic solutions (H_2SO_4) at different concentrations. Hydraulic conductivity tests were conducted for this purpose and lasted in some cases for 2 year to assess the CB mixtures chemical compatibility. This paper shows that the saline and acidic solutions can adversely affect the hydraulic performance of CB mixtures depending on SO_4^{2-} concentration and pH. At concentration of the order of 25 g/l or more, both solutions produced an initial decrease in the k value, followed by an increase and finally an almost constant trend of hydraulic conductivity with curing time. Swelling and a dense net of fixtures were detected on both samples after permeation due to ettringite formation. Sample thickness was found to affect the response of the CB mixtures when permeated with saline solutions. The authors indicated that the chemical conditions adopted in the tests are not expected to occur continuously in the field if a pumping system is provided so that there is an advective flow of groundwater and not of pollutant across the barrier.

Indrawan et al. present the findings of the work they have conducted on the effects on the hydraulic conductivity of compacted clays, commonly used for lining coal seam gas (CSG) water storage ponds, of moisture conditioning and permeation with CSG water. Four kaolinite-dominant clays were mixed with CSG and deionised waters and compacted to varying compaction degrees at different gravimetric moisture contents before permeation. Tests were conducted in a rigid wall permeameter (100 kPa hydraulic loading) and in an oedometer (100 kPa axial stress). The hydraulic conductivity of clays moisture-conditioned, compacted and permeated with saline CSG water ($k = 1 \times 10^{-11}$ m/s) was found to be similar to that of the same clays moisture-conditioned, compacted and permeated with deionised water. In both CSG and deionised waters, the compacted clay particles dispersed and the hydraulic conductivity decreased to a very low value of about 1×10^{-11} m/s. The hydraulic conductivities measured using a compaction mould permeameter were found to be comparable to, and a little higher than, those calculated from oedometer test data for the same compacted clays. The authors concluded that the clays investigated would be suitable as a liner for a CSG water storage pond.

Hanson et al. present the results of a laboratory investigation aimed at determining the moisture-suction relationships of geosynthetic clay liners (GCLs) under as-received conditions (moisture contents in the range of 14-27%) and subsequent to wet-dry cycles (20 cycles at 50% moisture content). Tests were conducted on three types of needle punched GCLs which contained granular bentonite. Two of the GCLs were of the conventional types whereas the third GCL was of a multi-component type (i.e. the carrier geotextile was composed of a non woven geotextile and a geofilm). Differences were observed between the conventional and multi-component GCLs and between the as-received and wet-dry cycled GCLs. The air entry suction value for the multi-component GCL was found to be lower than that for the conventional GCLs for the drying branches of the moisture suction curves and higher for the wetting branches of the curves. The residual suction value for the multi-component GCL was found to be higher than the residual suction values for the other two GCLs. The extent of hysteresis decreased and the differences between drying and wetting curves reduced for the wet-dry cycled specimens compared to the as-received specimens. Macro- and micro-structural variations determined through grain size distribution and SEM analyses (Fig. 3) indicated increasing void sizes and non-uniformity in fabric due to wet-dry cycling, supporting the observations made for variations in moisture-suction response.

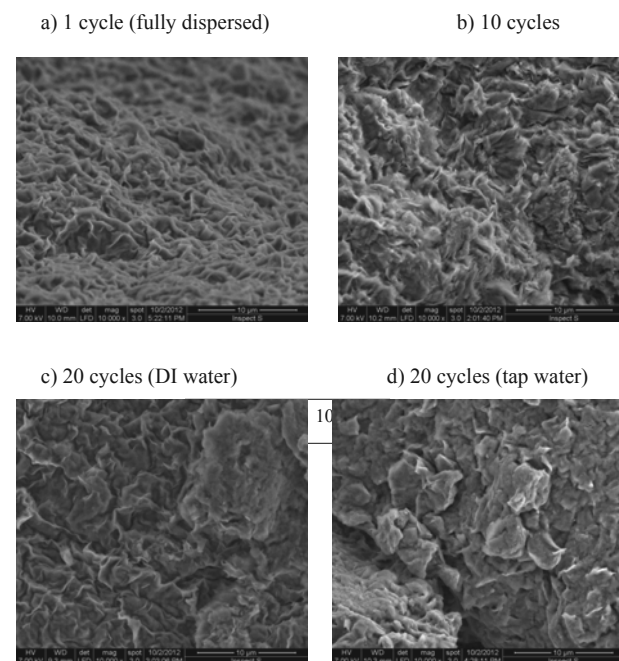


Figure 3. SEM images of bentonite from GCL specimens (Hanson et al. 2013)

Rayhani and Sarabadani describe a laboratory simulation study undertaken to quantify the hydration progress of Geosynthetic Clay Liners (GCLs) from underlying subsoils under simulated landfill conditions, before and after having been covered by municipal solid waste. GCL hydration was shown to be highly dependent on GCL manufacturing techniques, grain size distribution and initial moisture content of the subsoil. In particular, the difference in suctions between the GCLs and the type of subsoils was found to be an important factor governing the hydration process. The thermally treated, scrim-reinforced GCL demonstrated higher rate and degree of hydration compared to the other GCL products tested under similar conditions mainly due to the better anchorage of the connection layer against swelling of bentonite upon hydration.

Thermal cycles were found to severely suppress the moisture uptake of the GCL to as low as 15% of the moisture content observed under isothermal conditions. Seasonal cooling was shown to not guarantee sustainable hydration of the GCL provided that the GCL is subsequently exposed to daily thermal cycles. The authors suggest that the construction of a leachate collection system could provide the sufficient normal stress (2-5 kPa) for an adequately high rate of hydration as well as degree of hydration.

Monteiro et al. present the results of ramp and direct shear tests conducted on different geomembrane products (PVC and smooth and textured HDPE) in contact with a sandy soil prepared at various degrees of saturation. The results presented show that the interface friction angle between soil and geomembranes was insensitive to the variation of the soil degree of saturation. A progressive interface failure mechanism was observed in the tests with PVC geomembrane due to the more extensible nature of this type of geomembrane. The largest values of interface friction angles were obtained as expected with the textured HDPE geomembrane, whereas similar lower values were obtained with the smooth PVC and HDPE geomembranes.

3 MUNICIPAL SOLID WASTE AND OTHER TYPES OF WASTE GEOTECHNICAL PROPERTIES

Chen et al. propose a Bio-Hydro-Mechanical (BHM) coupled model to investigate solid-liquid-gas interaction behaviour in landfills containing municipal solid waste (MSW) with high organic content. The model also takes into account the release of moisture caused by the MSW biodegradation process. The development of the model is based on laboratory and in-situ investigations conducted on MSW to assess their hydraulic conductivity, gas permeability, and compressive and shear strength characteristics. The model was applied to hypothetical waste samples 5 m thick with properties similar to MSW from Qizishan landfill, China and Orchard Hills landfill, USA, to predict leachate production, gas pressure and settlement. Key problems relevant to waste management are also discussed in particular slope stability issues which can be caused by the presence of high organic content and consequently high water content and entrapment of gas pressures. Figure 4 shows that a mixture of leachate and landfill gas being ejected to a height of up to 5 m when drilling vertical extraction wells in Xiaping landfill, China. It indicates that the presence of very high pore and gas pressures may exist in the waste body if not managed properly and can be detrimental to the slope stability of a landfill.



Figure 4 . Ejection of leachate/gas (Chen et al., 2013)

Singh reports on the shear strength properties of municipal solid waste (MSW) and indicates that a factor which has not been paid much attention to is the highly compressible nature of MSW. It is suggested that due to the large compressibility of MSW at high normal stresses, a single Mohr Coulomb shear envelope for a landfill may not be applicable. A new approach

based upon the use of ‘Strength versus Depth’ plot has been proposed. It is argued that the use of strength versus depth plot is more appropriate for characterizing shear strength of MSW, especially for high landfills.

Cañizal et al. discuss the importance of determining the mechanical properties of MSW and their implication on landfill design. The paper highlights the difficulties in measuring these properties due to the nature of the material tested. The lack of samples representativeness for laboratory work and difficulties in interpreting field tests based on the experience gathered with conventional geotechnical materials have been cited as being major hurdles in obtaining reliable assessment of MSW mechanical properties. Back-analysis of failures was suggested as another possible approach to gather further information. However uncertainties still exist with this approach since failure cases are not frequent; and in the few cases which have occurred, it was difficult to detect the failure surface. A compilation of strength parameters obtained from laboratory and in situ tests and from failures (Figure 5) was presented.

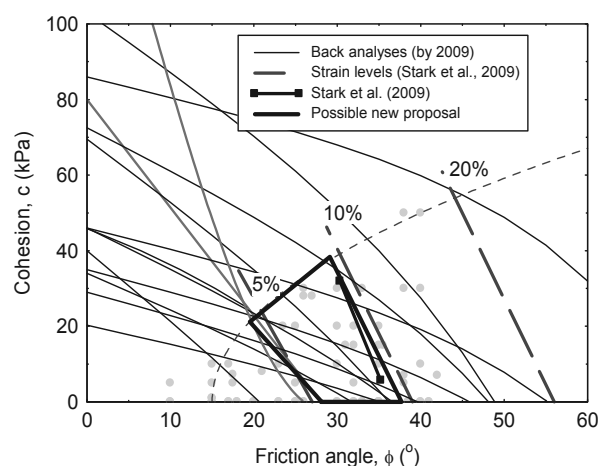


Figure 5. MSW strength parameters (*Cañizal et al.*, 2013)

Lavoie and Sinclair discuss the properties of a waste sludge which comprises primarily clay and iron-sands/grit originating from iron sands mining and in relation to its disposal in cells. This wet sludge waste is landfilled in cells to heights up to 25m. This paper shows that the characteristics of the sludge in situ are governed both by the nature of the material and the operation procedures. Key to the process is the limited height of each lift, together with the period of desiccation between lifts. To investigate the properties of the sludge for design input, boreholes and CPT's were put down through completed landfill cells of different ages. Field tests (boreholes and CPT's) on completed landfill cells of different ages showed that the in situ sludge experiences significant strength increase with time and depth, with pore pressures well below hydrostatic conditions. The sludge was assessed to be non-liquefiable based CPT data and Atterberg Limits gathered for this project.

4 SOIL AND GROUNDWATER REMEDIATION

Fronczyk and Garbulewski present a study on the influence of MSW landfill leachate on the hydraulic conductivity of zeolite-sand mixtures (with 50% and 20% content of zeolite). Results of the study indicate that the hydraulic conductivity of the reactive material has changed almost by two orders of magnitude (from 9.25×10^{-5} to 1.25×10^{-5} m/s). This change is believed to have been caused by the reduction of the effective porosity due to pore clogging. Analysis of calcium carbonate content showed no significant increase of carbonates in the samples, while scanning electron microscope study showed increased calcium content and formation of crystals of calcium

carbonate in the samples indicating that a precipitation process took place. Moreover, biological growth was observed indicating the presence of microbial activity.

Courcelles presents a study conducted on reactive filters for use in Permeable Reactive Barriers (PRB) to treat contaminants. One of the main geometric filter configurations consists in constructing an upward vertical filtration in a reactive filter. Crossing several meters of filter can generate excessive head losses, modify the regional flow and lead to a bypass of the system. A new radial-flow filter with a reduced filtration length has been developed to minimize these head losses. Physical tests have confirmed its hydraulic benefits since a reactive material with a hydraulic conductivity of 2.10^{-4} m/s after clogging was found to reduce the head loss by a factor of 4.5 when subjected to a radial filtration instead of a conventional vertical upward filtration. However, this result is strictly dependent on the ratio between the hydraulic conductivities of the coarse material and the reactive material. A minimum ratio of 50 was necessary to ensure a pseudo-vertical flow. This observation will improve the design of radial filters for tests at the pilot scale. It was concluded that in general, the use of radial hydraulic filter allows selection of the finest reactive materials, which is advantageous in chemical terms and makes it easier to meet the requirement for minimum ratio between the hydraulic conductivities of the coarse material and the reactive material.

Umezaki and Kawamura describe a zero-emission system to preserve the ecosystem in a closed water body such as a lake. The system is based on three processes: a) dredging of the lake bed soil; b) dehydration and purification to absorb nutrient salts; c) consolidation to reduce the volume of the dredged material after its return to the lake. Consolidation tests and column tests for bed mud and lake water sampled in Lake Suwa, Japan were conducted to simulate these processes. Natural zeolite powder was used as the absorbent for purification. Consolidation tests were carried out on the lake bed soil with natural zeolite powder as absorbent, and column tests were conducted to monitor the release inhibition of nutrient salts on the treated soil and lake water. It was reported that by applying about 30 kPa of low consolidation pressure, water contents approached the liquid limit and the volume decreased to about two-thirds. In the column test for bed mud with no treatment, total nitrogen (T-N), total phosphorus (T-P), and chemical oxygen demand (COD) surpass water quality standards for lakes in Japan. The release of nutrient salts from bed mud was clearly recognizable and algae developed in the water. To inhibit eutrophication, dehydration under 30 kPa and purification using natural zeolite powder was conducted; the contents of T-N and T-P were found to meet water quality standards for lakes. T-N decreased because of absorption of nitrogen by natural zeolite. Algae did not grow. The release inhibition effect for nutrient salts of natural zeolite was proved. However additional countermeasures against COD are still required.

Lugli and Mahler describe an in-situ remediation technique involving the uptake of contaminants by plant roots and their subsequent accumulation in plant tissues. The technique is referred to as Phyto-extraction. A numerical evaluation, using Hydrus 1-D, was conducted to evaluate the effectiveness of phytoremediation of Pb^{2+} and Zn^{2+} . The simulations considered soil and climatological data representative of the coastal lowlands of the municipality of Rio de Janeiro in Brazil and were organized in three steps: pre-contamination (analysis of the hydrological conditions), contamination (analysis of the contamination plume before planting) and remediation. It was indicated that, by modifying root depth and introducing irrigation, the phyto-extraction process could be optimized for contaminants characterized by low (e.g. Zn^{2+}) (Figures 6 and 7), and high (e.g. Pb^{2+}) retardation factors.

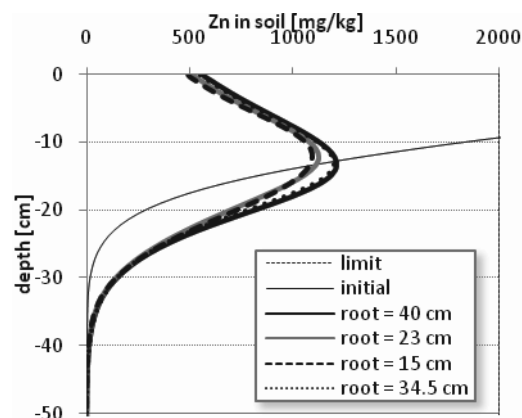


Figure 6: Zn^{2+} plumes: initial and after 10 years of remediation with different root depth (Lugli and Mahler, 2013)

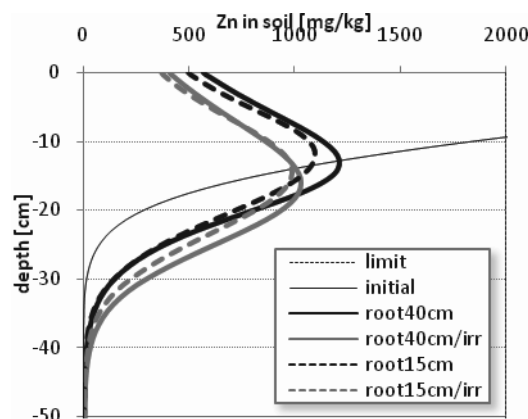


Figure 7: Zn^{2+} plumes: initial and after 10 years of remediation with different root depth and presence of irrigation (Lugli and Mahler, 2013)

Saadaoui et al. describe a new soil remediation technique using thermal in-situ desorption treatment (without excavation) referred to as NSRCityTM. The technique is based on heating the soil by conduction and extraction of the vapours of hydrocarbons released due to the heating process. The technique has already been used successfully on many urban and industrial sites in Europe and the United States. This technique was recently used in Belgium. The site contained a floating 0.5 m thick layer of hydrocarbons located at a depth of 3 m. A spacing of 1.5 m between heating tubes, allowed the site to be treated within 70 days.

Jones describes the integration of geotechnical, environmental and groundwater investigations for the Terminal 4 Project in Newcastle, Australia, aimed at identifying appropriate remediation measures to protect human health and environmental values. It discusses the various remediation methods proposed for the safe development of the site. Methods considered (see Fig. 8) include soil-bentonite cut off walls to deal with tar waste, permeable reactive walls to tackle asbestos/lead contaminants, multi-phase extraction (MPE) to extract free-phase LNAPL contamination, followed by monitored natural attenuation (MNA) for residual dissolved phase hydrocarbon contamination and installation of a low-permeability geosynthetic clay liner (GCL) over the site for protection purposes. The Terminal 4 Project (Fig. 8) is expected to improve the long-term environmental condition of a site previously contaminated by industrial waste, while protecting the surrounding sensitive environment.



Figure 8. Remediation Plan (Jones, 2013)

Flores et al. present a simplified image analysis method to assess the saturation distribution of water and Non-Aqueous Phase Liquids (NAPLs) of different densities and viscosities ($0.73 \leq \rho \leq 1.20 \text{ g/cm}^3$; $1.4 \leq \nu \leq 1000 \text{ mPa}\cdot\text{s}$) in granular soils subject to fluctuating groundwater conditions. This study has confirmed that the relationship between Optical Density (D_i) and water and LNAPL saturation values (S_w and S_o) is approximate linear, as predicted by the Beer-Lambert Law of Transmittance, for ten different NAPLs. Based on these findings, it was concluded that the Simplified Image Analysis Method can be safely used to assess water and NAPL saturation distributions in porous media subject to dynamic conditions, for a broad range of NAPLs. Furthermore, the authors applied this method to study the behaviour of five different NAPLs in experimental columns subject to drainage and imbibition processes, and confirmed that light NAPLs can effectively get trapped below the water table, despite their lower densities than water.

Inoue et al. describe a new methodology based on using spatial moment analysis linked with image processing of a dye tracer behaviour in porous media to estimate dispersivities in longitudinal and in transverse directions. Laboratory and field tracer experiments using a relatively mobile dye tracer referred to as Brilliant Blue FCF were conducted under saturated and unsaturated flow conditions. Dispersivities were found to exhibit an increasing and decreasing tendency associated with water content and showed a dependency on infiltration rates. Experimental results showed the effectiveness of the new methodology for simultaneous assessment of transverse and longitudinal dispersion in unsaturated soils in field as well as in laboratory.

Inui et al. address the issue of excavating stratum that naturally contain heavy metals due to their geologic histories. This paper addresses the long term leaching characteristics of arsenic and lead in several rock materials, which were weathered in outdoor for more than two years. Several laboratory tests were conducted to estimate the long term leaching characteristics of As and Pb in several rock materials, and then comparing to the results obtained from outdoor exposure tests. It was concluded that total contents of trace metals can be regarded possibly as screening values to judge whether detailed evaluation of leaching characteristics is necessary. The leaching amount of As obtained in the conventional batch leaching test was found to be a good index of field leaching amount, and the accelerated oxidation tests were shown that they could simulate the outdoor leaching amount on the safe side.

5 BIOGEOCHEMISTRY

Omine et al. describe a geo-environmental approach used to restore farmed land which was damaged by salinity, due to

tsunami water triggered by the mega earthquake that hit the Pacific coast of the Tohoku region in Japan in March 2011. As a consequence of this event, the pH and EC of the agricultural soil increased and exceeded the safer limits for cultivated crops. Compost containing Halo bacteria/salt tolerance bacteria was used to restore the farmland. Chemical analysis and potting cultivation were performed on the saline soils. It was shown that the compost containing salt tolerance bacteria can reduce the excessive salts and consequently reduce the salinity problem. It was also confirmed that the compost was effective for growth of rice plants. The compost also provided necessary nutrients to the soil and plant. However, it was not easy to distinguish clearly in the field application the effect of the compost with salt tolerance bacteria due to decrease of salt concentrations caused by rainfall and vegetation.

Sassa et al. describe a new Ecological Geotechnics approach. They investigated the linkage between the waterfront environment and the burrowing activity of six species of invertebrates in intertidal flats through a series of controlled laboratory experiments on the benthos-soil systems. The experimental results show that there exist both suitable and critical environmental conditions for the burrowing activities of the diverse species irrespective of burrowing types, growth stages and weights. On the basis of these results, an ecohabitat chart was developed revealing complex interrelationships among species between suitable and critical environmental conditions. Validation of the chart was conducted through an integrated field observations, surveys and analyses of the waterfront environment and the species distributions at five natural and artificial intertidal flats. The results demonstrate that the way and where the diverse species lived are well consistent with the ecohabitat chart developed in this study. It was concluded that the results obtained succeed not only in answering the fundamental question of why intertidal flats foster a complex ecosystem by the diverse species, from a viewpoint of Ecological Geotechnics, but also established a new rational basis which can facilitate the conservation and restoration of habitats with rich natural ecosystems in intertidal zones.

Stewart et al. review techniques from molecular biology for characterising microbial populations that are accessible to Geotechnical or Geo-Environmental Engineers. With reference to data from contaminated land studies, the paper discusses which techniques might be appropriate to use in an engineering context, how the data generated can be visualised and interpreted, and the dangers of over interpretation. Polymerase chain reaction (PCR), a technique for replicating a selected section of a DNA fragment, based methodologies have been proposed to manage populations of microorganisms available in soils. PCR permit the detection of the microbes present and how they change with changing conditions. It is relatively easy to use in an engineering setting and the availability of reagents in kit form along (with detailed protocols) means that the barriers to adoption are reasonably low. The paper stress the fact that this is a rapidly moving field and the advent of high throughput deep sequencing technologies have led to the development of 'metagenomics' and 'metatranscriptomics' which investigates the composite genetic potential of an ecological niche. The authors indicate that instrumentation and cost of sample analysis are still relatively high but likely to fall as capacity and technology increase. In addition, the sheer volume of data generated poses a significant challenge in terms of bioinformatics and fully exploiting these technologies will require multidisciplinary collaborations between engineers, molecular biologists and informaticians.

6 CONCLUSIONS

Twenty two (22) papers have been allocated to this session. They described and presented laboratory and field studies and numerical modelling addressing numerous topics which included novel materials, chemical compatibility of barrier materials, unsaturated behaviour of geosynthetic liners, geosynthetic liner interface behaviour, waste geotechnical properties, phytoremediation, permeable reactive barriers, soil remediation, image analysis, natural leaching of heavy metals and biogeotechnology. This general report offers a review of all the papers submitted to this session and highlights the major findings reported by the authors of these papers.

List of papers submitted to this session

- Bohnhoff, G., Shackelford, C., Malusis, M. Scalia, J., Benson, C., Edil, T., Di Emidio, G., Katsumi, T. and Mazzieri, F. (2013). Novel bentonites for containment barrier applications. Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris 2013
- Brianzoni, V., Fratolocchi, E. and Pasqualini, E. (2013). Long term performance of cement-bentonite cut-offs in saline and acidic solutions. Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris
- Cañizal, J., Lapeña, P. Castro, J. A. da Costa, A., Sagasetta, C. (2013). Determination of shear strength of MSW. Field tests vs. laboratory tests. Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris
- Chen, Y.M., Zhan, L.T., Xu, X.B. and Liu, H.L. (2013). Geo-environmental problems in landfills of MSW with high organic content. Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris
- Courcelles, B. (2013). Experimental study of radial filtration in Permeable Reactive Barriers (PRB). Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris
- Flores, G., Katsumi, T., Inui, T. and Takai, A. (2013). Measurement of NAPL saturation distribution in whole domains by the Simplified Image Analysis Method. Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris
- Fronczyk, J. and K. Garbulewski, K. (2013). Hydraulic conductivity of zeolite-sand mixtures permeated with landfill leachate. Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris
- Hanson, J.L., Risken, J.L. and Yeşiller, N. (2013). Moisture-retention relationships for geosynthetic clay liners. Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris
- Indrawan, I.G.B, Williams, D.J. and Scheuermann, A. (2013). Hydraulic conductivity of compacted clay liners moisture-conditioned and permeated with saline coal seam gas water. Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris
- Inoue, K., Shimada, H. and Tanaka, T. (2013). Simultaneous estimation of transverse and longitudinal dispersion in unsaturated soils using spatial moments and image processing. Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris
- Inui, T., Katsumi, T., Takai, A. and Kamon, M. (2013). Evaluating the long-term leaching characteristics of heavy metals in excavated rocks. Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris
- Jones, S. (2013). Geo-environmental challenges of a major coal terminal development in Australia. Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris
- Lavoie, J.L.N. and Sinclair, T.J.E. (2013). Characterisation of landfill steel mill sludge waste in terms of shear strength, pore water pressure dissipation and liquefaction potential. Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris
- Lugli, F. and Mahler, C.F. (2013). A numerical analysis of phytoextraction. Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris
- Monteiro, C.B., Araújo, G.L.S., Palmeira, E.M. and Cordão Neto, M.P. (2013) Soil-geosynthetic interface strength on smooth and textured geomembranes under different test conditions. Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris
- Omine, K., Moqsud, M.D. A and Hazarika, H. (2013). Geoenvironmental approach to restoration of agricultural land damaged by tsunami. Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris
- Rayhani, M.T., and Sarabadani, H. (2013). Factors affecting hydration of Geosynthetic Clay Liners in landfill applications. Proceedings of the 18th International Conference on Soil Mechanics and Geotechnical Engineering, Paris
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